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Shear Behavior of Self Compacting R.C. I-Beams

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Abstract

Twelve SCC I-Beams were designed to investigate the shear behavior under two concentrated loads. All beams have the same longitudinal steel ratio of (0.0145) and gross section area of (29000 mm^2). The tested beams were divided into two groups with and without stirrups. The first group consist of three beams without stirrup having different values of compressive strength (fc`) but same value of clear span to effective depth ratio (ln/d), while the second group consist of nine beams with stirrups. It shall divided into three series according to the compressive strength (fc`) each series continued three beams at different value of clear span to effective depth ratio(ln/d).it was found that The ultimate shear strength predicted from A CI 318-08 is lesser than the experimental values, the ultimate shear strength of SCC I-beams increased about 46.728%,46.55%and 41.462% when the clear span to the effective depth (ln/d) decreased from (5.84 to 5.05) at compressive strength (fc) 29.36, 41.42 and 49.2 MPa respectively ,the ultimate shear strength for SCC I- beams with stirrups increase about 22.536%.15.27%and 10.828% when the compressive strength(fc) increased from (29.36 to 49.2 MPa) at clear span to effective ratio (ln/d) 5.84, 5.5 and 5.05 respectively, ,the ultimate shear strength of SCC I-beams with stirrups increased about 42.66%, 38.09% and 39.77% as compared with ultimate shear strength without stirrups at compressive strength 29.36,41.42 and 49.2 MPa respectively.

Key words: shear strength, without stirrups, with stirrups, self compacting concrete, I-Beams.

1. Introduction

Self compacting concrete (SCC), is a new kind of high performance concrete (HPC) with excellent deformability and segregation resistance. It is a flowing concrete without segregation and bleeding, capable of filling spaces in dense reinforcement or inaccessible voids without hindrance or blockage. The composition of SCC must be designed in order not to separate and not to excessively bleed. Concrete strength development is determined not only by the water-to-cement ratio, but also is influenced by the content of other concrete ingredients like cement replacement material and admixtures(1).

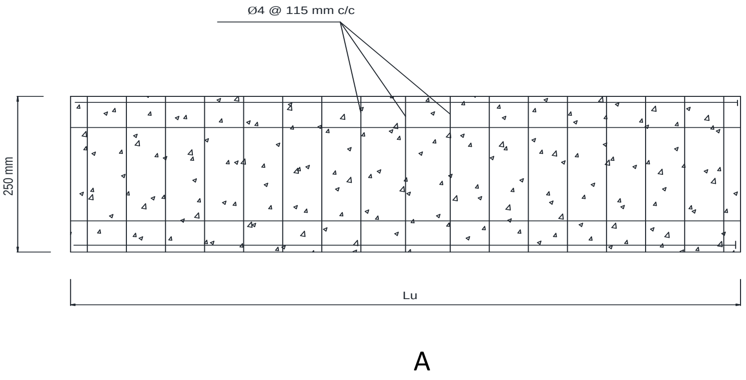
2. Research significance

Concrete has been used in the construction industry for centuries. Many modification and developments have been made to improve the performance of concrete, especially in term of strength and workability. Engineers have found new technology of concrete called self compacting concrete. The principal objective of the work described in this study is to investigate and to get more information and better understanding of the shear Behavior of self compacting concrete I-beams .

3. Experimental program

3.1 Description of specimens

The Tested beams are divided into three groups according to the overall length of 1500, 1400 and 1300 mm. The cross section has overall dimension of 250 mm total depth and width of flange 200 mm. The longitudinal steel reinforcement consist of four bar (8 mm diameter of the bar, area of (50.265mm^2) lay in one layer at the bottom and four bar (4 mm diameter, area of (12.566 mm2) laid in one layer at the top. The internal steel stirrups are (4 mm) in diameter (12.566 mm2) at spacing 115 mm center to center as shown in fig.(1). The total description of the beams which used in this study are listed in table (1),the test set-up is shown in fig. (2) and the total description of the beams which used in this study are listed in table (1).



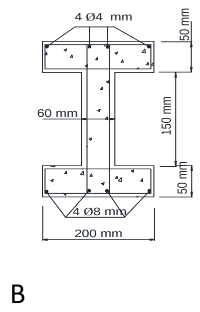


Fig (1) details of specimens all dimension in mm: (A) elevation; (B) cross-section

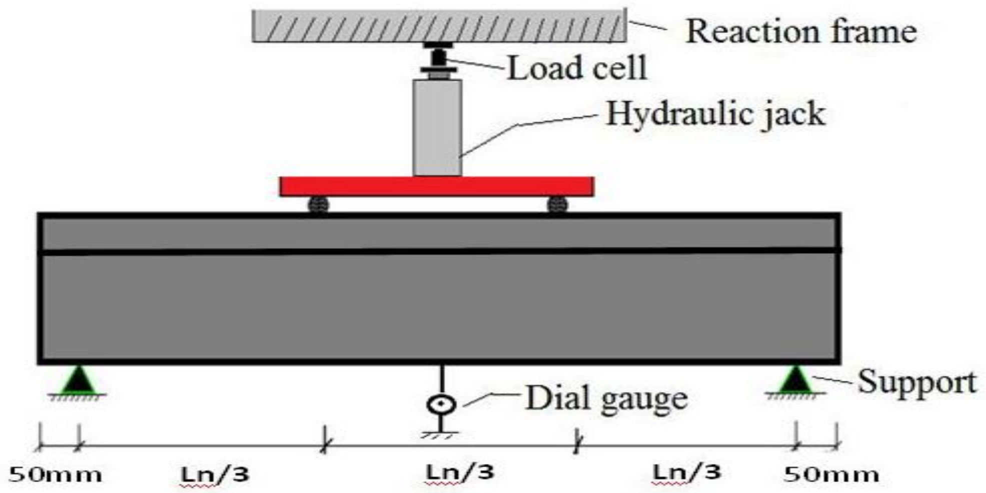


Fig (2) Beams specimen setup

Table (1): Total description of the tested beams

Group	Beam	Comp. strength (f'_c) MPa	Clear span (ln)mm	Effective depth (d)mm	Width of flange (bf)mm	Width Of web (bw)mm	Longitudinal steel ratio
Beams without stirrups	A10	29.39	1400	230	200	60	0.0145
	B10	41.4	1400	230	200	60	0.0145
	C10	49.2	1400	230	200	60	0.0145
Beams with stirrups	A11	29.39	1400	230	200	60	0.0145
	A12	29.39	1300	230	200	60	0.0145
	A13	29.39	1200	230	200	60	0.0145
	B11	41.4	1400	230	200	60	0.0145
	B12	41.4	1300	230	200	60	0.0145
	B13	41.4	1200	230	200	60	0.0145
	C11	49.2	1400	230	200	60	0.0145
	C12	49.2	1300	230	200	60	0.0145
	C13	49.2	1200	230	200	60	0.0145

3.2 Materials

General description and specification of materials used in the investigation are listed below, tests are made in the Materials Laboratory , College of Engineering Al-Mustansiriya University.:

Cement : Ordinary Portland cement Type I produced at northern cement factory (Tasluja-Bazian) is used throughout this investigation which conforms to the Iraqi specification No. 5/1984(2).

Fine Aggregate: Al-Ukhaider natural sand is used. The used sand complies with the Iraqi Standard Specification No.45/1984(3).

Coarse Aggregate: Crushed gravels from Al-Nibaee area are used in this study. The used gravels complies with the Iraqi Standard Specification No.45/1984(3).

Water: Ordinary potable water is used throughout this work for both mixing and curing of concrete.

Steel Reinforcement: Deformed steel bars with nominal diameter of 8mm and 4mm were used in this study. Yield tensile strength were 400MPa,and 350 MPa,for (8mm) and (4mm) bars receptively

Limestone Powder: A fine limestone powder (locally named as Al-Gubra) of Jordanian origin with fineness of (3100 gm/cm^2) is used to avoid excessive heat generation, enhance fluidity and cohesiveness, improve segregation resistance and increase the amount of fine powder in the mix (cement and filler). According to EFNARC [4], the fraction less than 0.125 mm will be of most benefit.

Super plasticizer: for production of High-Performance Concrete, a super plasticizer is used throughout this study. It is known commercially as "GLENIUM51" and it is brought from Degussa Construction Chemicals. It is a new generation of modified polycarboxylic ether. It is suitable for the production of SCC. Also, it is free from chlorides and complies with ASTMC494 types A and F. It is compatible with all Portland cements that meet recognized international standards [5].

3.2.3 Mix Design for Self-compacting Concrete

Mix proportioning is more critical for SCC than for NSC and HSC. Many trials are carried out on mixes incorporating superplasticizer by increasing the dosage of the admixture gradually, adjusting the w/c ratio to ensure the self-compact ability. Tables (2) indicate the mix proportion of SCC mix. For each concrete mix, three cylinder specimens are taken and tested at 28 days of age days, the test result of fresh concrete properties are shown in table (3) these results are within the acceptable criteria for SCC given by ACI committee-363(6), and indicate excellent deformability without blocking .

Table (2): mix design of SCC mixes by weight

Group	Cube Strength () MPa f_{cu}	Cylinder Strength (f'_c) MPa.	Mix proportions kg/m³						L /m³	
			W/C Ratio	Cement	Lsp	Total powder	Sand	Gravel	Water	Glenium51
A	36.3	29.36	0.55	346	204	550	743	833	190	6.6
B	51.74	41.42	0.55	474	105.3	357.3	758.4	833	180	8.1
C	59.2	49.2	0.38	535	64	599	814	833	155	18

Table (3): Results of testing fresh SCC property in experimental work

Mix symbol	Slump flow (mm)	T50 Sec.	L-box (H2/H1)	T20 Sec.	T40 Sec.
A	750	2.6	0.96	1.8	3.5
B	715	3.8	0.90	2.1	3.9
C	685	4.9	0.88	2.3	4.2

Acceptance criteria for Self-compacted concrete (SCC) [7]

NO.	Method	Unit	Typical range of values	
			Minimum	Maximum
1	Slump flow	mm	650	800
2	T50	Sec	2	5
3	L-Box	(H2/H1)	0.8	1

4. Shear strength of concrete according to ACI-318 provision

According to ACI 318-08, shear capacity of reinforced concrete beams (v_n) can be calculate as follows[(5)]:

$$V_n = V_c + V_s \qquad \text{……………… Eq. (1)}$$

$$V_c = \frac{\sqrt{f'_c}}{6} b_w \ d \qquad \text{………………Eq.(2)}$$

$$V_c = (\sqrt{f'_c} + 120 \ \ell w V_u d/M_u) b_w d/7 \qquad \text{…………….. Eq. (3)}$$

$$V_s = Av \ \ f_y \ d \ / \ S \qquad \text{…………………. Eq. (4)}$$

Where:-

V_c and V_s are shear transfer capacity of concrete and shear reinforcement respectively; Mu and Vud are factored moment and shear force; $\ell_w = As/b_w d$ is the longitudinal bottom reinforcement ratio; As is the longitudinal bottom reinforcement area; b_w is the width of the web; d is the effective depth; A_v is the vertical shear reinforcement area, S is the spacing between the vertical stirrups reinforcement; f'_c is the compressive strength of concrete and f_y the yield strength of shear reinforcement

According to clear span to effective depth ratio (ln/d) the main variable in this research , Eq.(3) will be used since the shear stress at cracking will depend on the bending moment and shear force at critical section ratio (Vud/Mu)and the longitudinal steel ratio (ℓ_w) that lead to reduce the shear crack and improved the ultimate strength.

Table (4) compared the ultimate shear strength obtained from tested of SCC beams with that obtained by using the ACI 318-08 provisions, by the inspection of Table (4) shown below it can be noted that the ultimate shear strength predicated from ACI 318-08 is lesser than the experimental values because of the SCC will improved durability, and increased bond strength(7).

Table (4): comparisons of tested results

Beam	Ultimate shear strength (Vu kN)tested	Nominal shear strength (Vn kN) ACI	$\frac{V_{u\,test}}{V_{N\,ratio}}$
A10	37.5	14.127	2.654
A11	53.5	31.719	1.6866
A12	72	31.719	2.269
A13	78.5	31.719	2.474
B10	42	16.1328	2.603
B11	58	33.725	1.454
B12	80	33.725	2.372
B13	85	33.725	2.66
C10	44	17.273	2.543
C11	61.5	34.866	1.764
C12	83	34.866	2.380
C13	87	34.866	2.495

5. Results

5.1 . Load capacity of the tested beams

The relationship between the applied load and the deflection for the tested beams is shown in fig.(3) to fig.(6). At every stage of loading, the deflection at mid-span is obtained by dial gage at mid span, it can be noticed that:

- During the early stage of loading no interface slip is recorded and this continue until the applied loading is equal to first crack loading approximately, Beyond the first crack loading each beams behaved in a certain manner.
- The ultimate shear strength of SCC I-beams with stirrups increased when the compressive strength increased as shown fig.(7). The ultimate shear strength increase about

22.536%.15.27%and 10.828% when the compressive strength increased from (29.36 to 49.2 MPa) at clear span to effective ratio (ln/d) 5.84, 5.5 and 5.05 respectively as shown in table (5) .

- The ultimate strength of SCC I-beams without stirrups increased when the compressive strength increased as shown in fig.(8), the ultimate shear strength increased about 17.33% when the compressive strength increased from (29.36 to 49.2 MPa).
- The ultimate shear strength decreased when The clear span to the effective depth ratio (ln/d) increased as shown in fig (9), the ultimate shear strength of SCC I-beams increased about 46.728%,46.551%and 41.462% when the clear span to the effective depth (ln/d) decreased from (5.84 to 5.05) at compressive strength (fc) 29.36, 41.42 and 49.2 MPa respectively as shown in table (6)
- The ultimate shear strength of SCC I-beams with stirrups is greater than SCC I-beams without stirrups as shown in fig.(10),the ultimate shear strength of SCC I-beams with stirrups increased about 42.66%, 38.09% and 39.77% as compared with ultimate shear strength without stirrups at compressive strength 29.36,41.42 and 49.2 MPa respectively, as shown in table (7).

5.2 Failure mode

As expected, all the tested beams failed in shear as shown in fig.(7),the diagonal crack form. The beams remains stable after such cracking. Further increase in shear force will cause the diagonal crack to penetrate into the compression zone at the loading point, until eventually crushing failure of concrete occurs there[8].

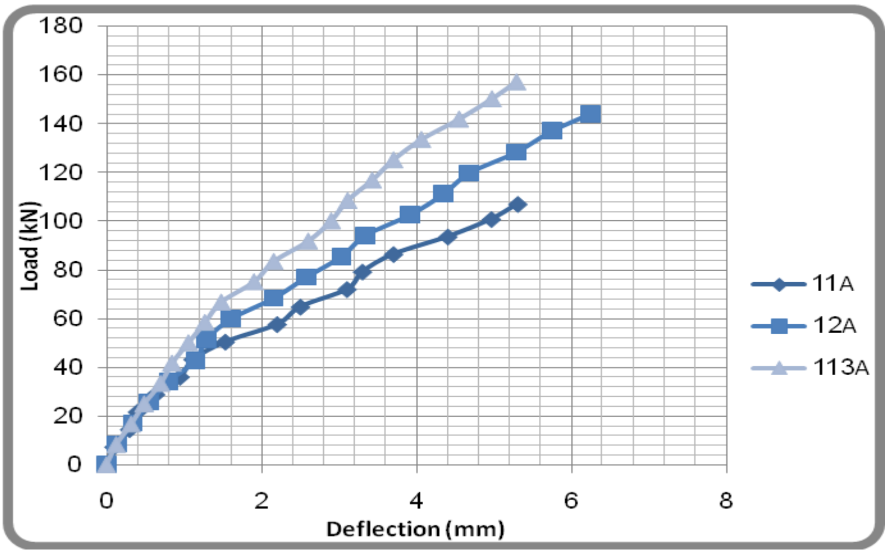


Fig.(3) load – deflection curve for SCC I- beams with stirrups at Compressive strength (f'_c)=29.36 MPa

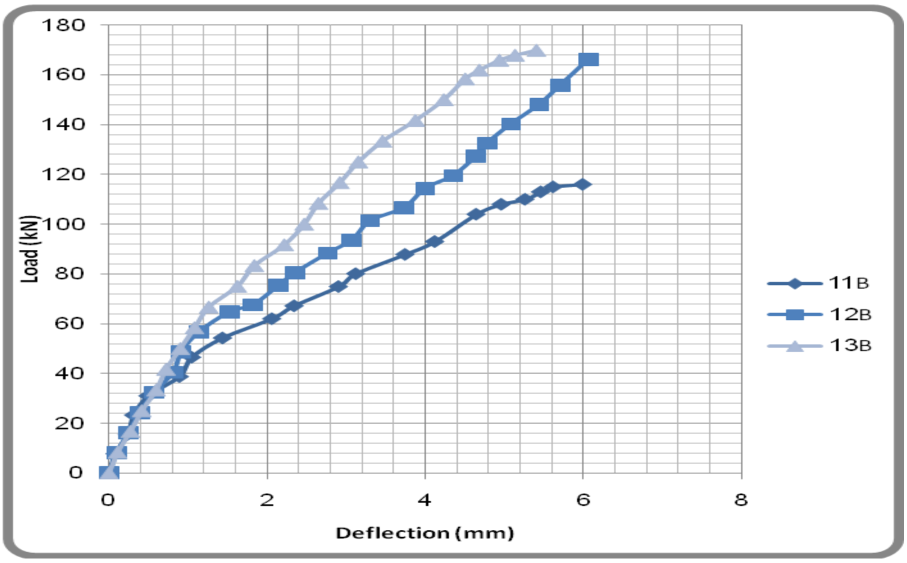


Fig.(4) load –deflection curve for SCC I- beams with stirrups at Compressive strength (f'_c)=41.42 MPa

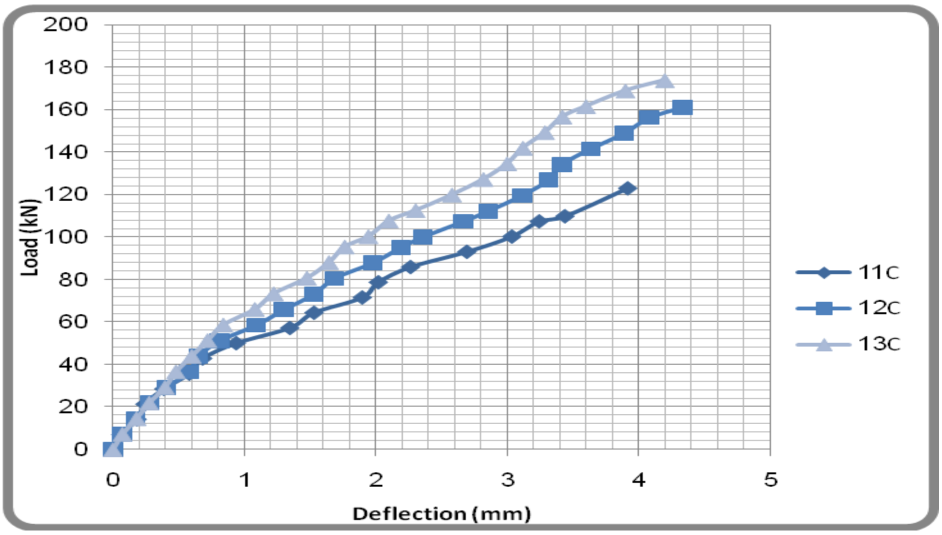


Fig.(5) load –deflection curve for SCC I- beams with stirrups at (f'_c)=49.2 MPa.compressive strength

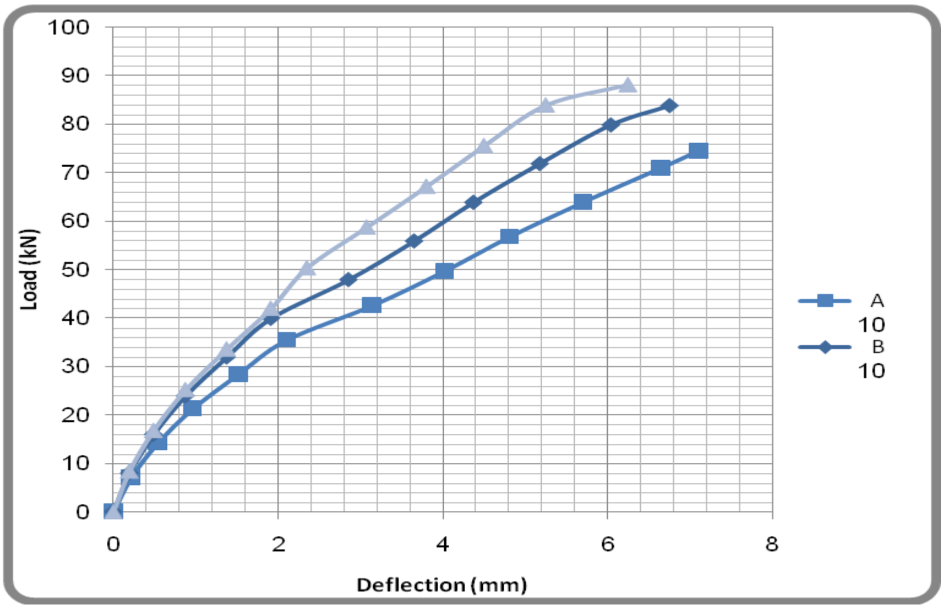


Fig.(6) load –deflection curve for SCC I- beams without stirrups at clear span to effective depth ratio (Ln/d) = 6.086

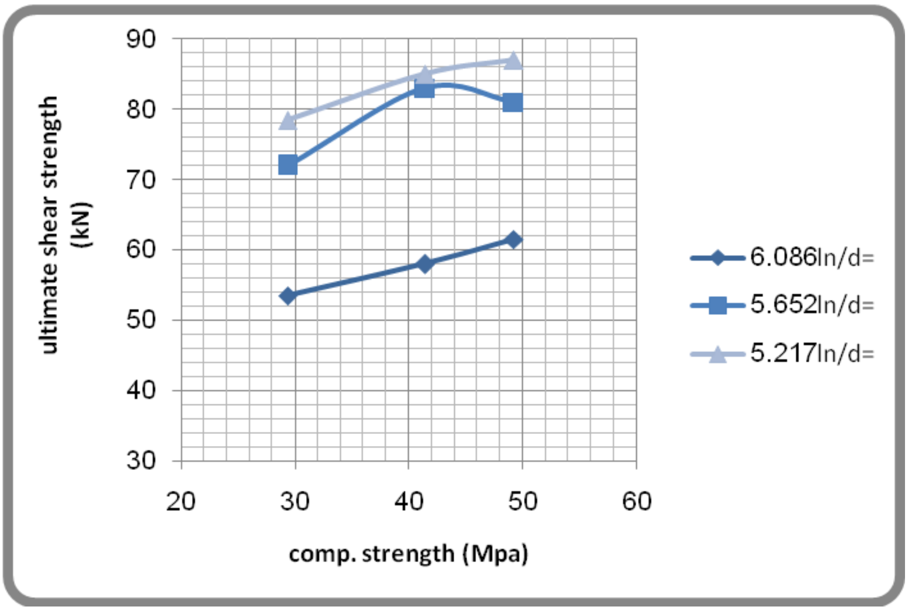


Fig.(7) effect of compressive strength (fc) for SCC I- beams with stirrups on the ultimate shear strength.

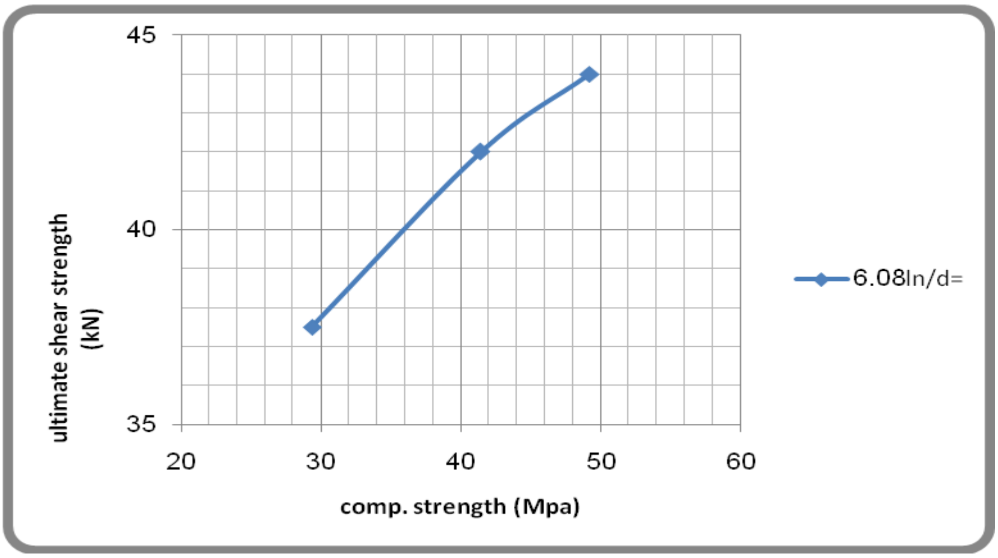


Fig.(8) effect of compressive strength the ultimate shear strength. (f'_c) for SCC I - beams without stirrups on

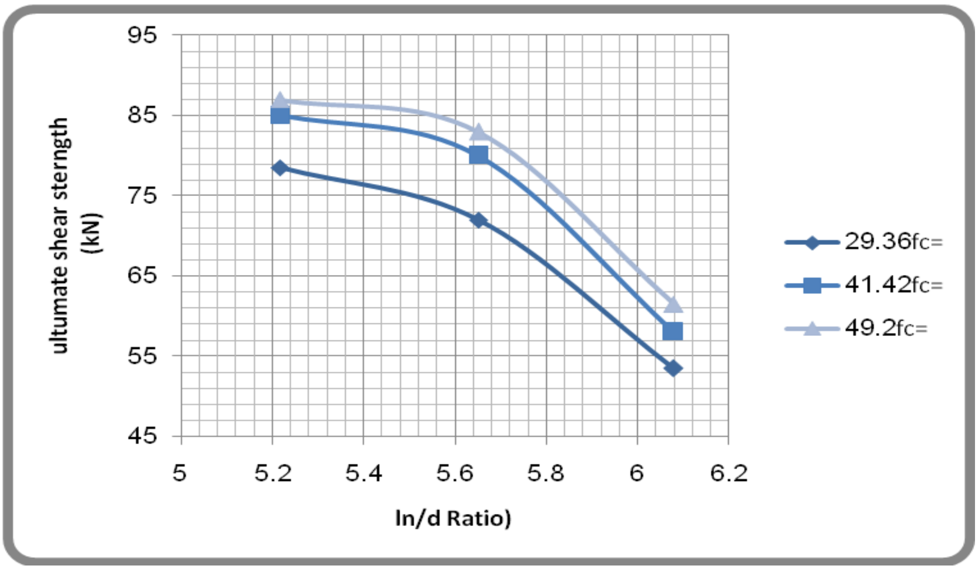


Fig.(9) effect of clear span to the effective depth ratio(ln/d) on the ultimate shear strength.

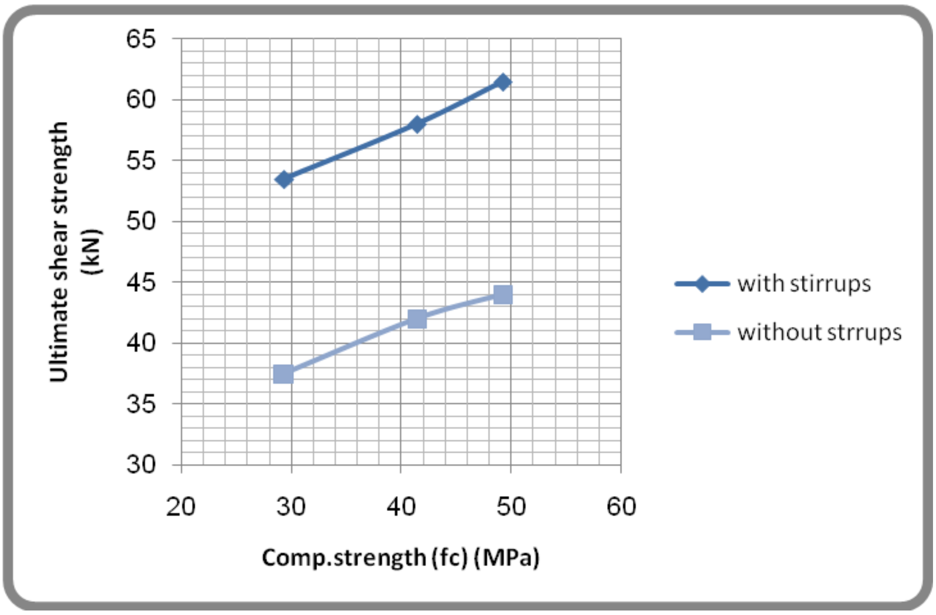


Fig.(10) effect of absence of stirrups on the ultimate shear strength

Table (5): effect of compressive strength (f'_c) on the percentage increased in the ultimate shear strength.

Group	Clear span to effective depth ratio (ln/d)	Compressive strength (f'_c) MPa.	Ultimate shear capacity (Vu) kN	Percentage of increased %
Without stirrups	6.08	29.36	37.5	-------
		41.42	42	12
		49.2	44	17.33
With stirrups	6.08	29.36	53.5	-------
		41.42	58	8.411
		49.2	61.5	22.535
	5.652	29.36	72	-------
		41.42	80	11.111
		49.2	83	15.277
	5.217	29.36	78.5	-------
		41.42	85	8.280
		49.2	87	10.828

Table (6:) effect of clear span to effective depth ratio (ln/d) on the percentage increased in the ultimate shear strength

Group	Compressive strength (f'_c) MPa.	Clear span to effective depth ratio (ln/d)	Ultimate shear capacity (Vu)kN	Percentage of increased %
With stirrups	29.36	6.08	53.5	-------
		5.652	72	34.579
		5.217	78.5	46.728
	41.42	6.08	58	-------
		5.652	80	37.931
		5.217	85	46.551
	49.2	6.08	61.5	-------
		5.652	83	34.959
		5.217	87	41.463

Table (7): effect of absence of stirrups on the percentage increased in the ultimate shear strength.

Beams	Compressive strength (f'_c) MPa.	Ultimate shear capacity (Vu)kN	Percentage of increased %
A10	29.36	37.5	-------
A11	29.36	53.5	42.66
B10	41.42	42	-------
B11	41.42	58	38.09
C10	49.2	44	-------
C11	49.2	61.5	39.77

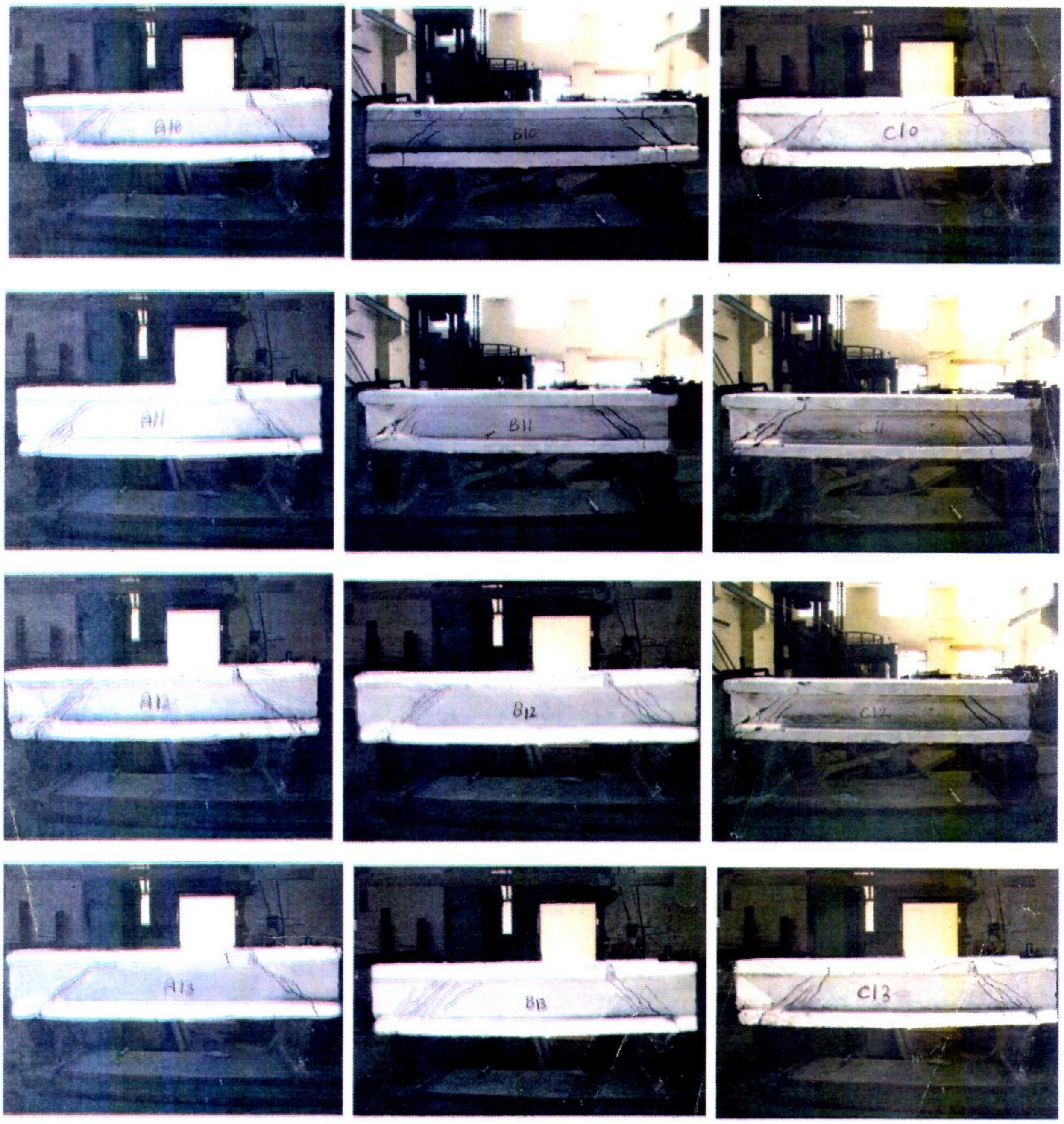


Fig. (11) crack pattern of SCC I-beams

6. Conclusion

Base on the results of this experimental investigation of evaluation of shear strength of SCC I-beams, the following conclusion are drawn:

- The workability requirement for successful placement of SCC necessity that the concrete should exhibits excellent deformability and proper stability to flow under its own weights without segregation and blockage.
- The ultimate shear strength predicated from ACI 318-08 is lesser than the experimental values.
- The ultimate shear strength decreased when the clear span to the effective depth ratio increased, the ultimate shear strength of SCC I-beams increased about 46.728%,46.55%and 41.462% when the clear span to the effective depth (ln/d) decreased from (5.84 to 5.05) at compressive strength (fc) 29.36, 41.42 and 49.2 MPa respectively .
- The ultimate shear strength of SCC I-beams with stirrups increased when the compressive strength (fc) increased, The ultimate shear strength increase about 22.536%.15.27%and 10.828% when the compressive strength(fc) increased from (29.36 to 49.2 MPa) at clear span to effective ratio (ln/d) 5.84, 5.5 and 5.05 respectively.
- The ultimate shear strength of SCC I-beams without stirrups increased when the compressive strength increased, the ultimate shear strength increased about 17.33% when the compressive strength increased from 29.36 to 49.2 MPa.
- The ultimate shear strength of SCC I-beams with stirrups is greater than SCC I-beams without stirrups ,the ultimate shear strength of SCC I-beams with stirrups increased about 42.66%, 38.09% and 39.77% as compared with ultimate shear strength without stirrups at compressive strength 29.36,41.42 and 49.2 MPa respectively.

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